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ABSTRACT

Presented is a discussion of the components and concepts of an ecology typical of the coastal southeastern United States. Principles presented are applicable to other areas. The discussion includes several major sections: the environment, wildlife management, freshwater ecosystems, and the estuarine environment. Numerous figures and illustrations supplement the discussions. (RE)

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# Concepts in Environmental Education

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## Introduction

This course is about the ecology of South Carolina, but the principles presented here are applicable anywhere. Although the course will cover such separate subjects as geology, forestry, and game management, it should be remembered that the environment functions as an integrated system whose parts cannot be separated.

## The Environment

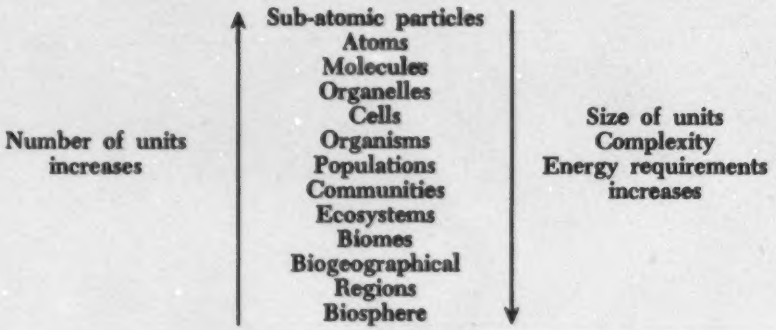
Heredity determines what an organism *can* do; the enviro ment determines what an organism *will* do. This statement is true for all living things, people as well as lower animals. A child might receive genes for musical ability, but unless he develops his talent it will never be realized. So too might an animal or a plant contain genes for strong and vigorous growth, but if certain nutrients are missing from the diet or the soil, the organism will be weak and not grow to its potential.

The environment of an organism is everything around it. It is easier to think of the environment as consisting of two major parts: the *abiotic* and the *biotic* environment. The abiotic environment includes *nonliving things* such as water or minerals, and *conditions* and *influences* such as temperature, sunlight, or wind. The biotic environment includes all *living things* that, directly or indirectly, influence the life of an organism.



Before going on with the discussion of the environment we need to look first at the way all matter is arranged. Scientists recognize about twelve levels of organization of matter and three principles that pertain to them. Refer to Figure 1 as you read the following section.

**Figure 1. Levels of Organization**



*Sub-atomic* particles are mainly electrons, protons, and neutrons that are held together to form atoms. *Atoms* when they react together form molecules. *Molecules* unite into complex structures and form organelles within cells. One *cell* can constitute a complete organism, such as an amoeba, or many cells may be required to form an *organism*. An organism is any living thing. A *population* is a group of organisms of the same species. All of the populations within a given area form a *community*. An *ecosystem* is made up of the community and the nonliving or abiotic features of the environment within a given area. *Biomes* are large regions that have had a dominant plant type over a long period of time. Examples of biomes are: grassland, tundra, desert, deciduous forest, or rain forest. *Biogeographical regions* are generally continential areas that have become isolated by natural barriers such as oceans, deserts, and mountains. The plants and animals in these regions are not generally found anywhere else and are said to be "indigenous". Australia with its marsupials is a good example of one of these regions. The *biosphere* is simply that portion of the earth, sea and atmosphere which will support life.

Notice that as we move from sub-atomic particles to higher levels of organization the number of units in each level decreases. In other words there are many more atoms in the world than there are organisms, and there are many more organisms in the world than biomes. Also as we move to higher levels of organization the size of each unit increases; for example, organisms are larger than organelles. Also increasing with each higher level is the complexity and the amount of energy needed to keep that level functioning. If we stop to think about these things we will see that it is fairly logical. The most important aspect of these levels of organization, however, are the principles that pertain to them.

The first principle says that each level has a set of characteristics peculiar to that level. For example, the characteristics or attributes of atoms are not the same as those of molecules. Atoms cannot be easily split whereas molecules can. The second principle is that the characteristics of the lower levels cannot be added up to arrive at the characteristics of a higher level. Atoms of hydrogen are a gas, as are atoms of oxygen. But when they unite to form the molecule water, the characteristics of water are different. Water is a liquid. This brings us to the third principle. It says that the characteristics of lower levels cannot be added up to arrive at the characteristics of a higher level because of the particular arrangement or "organization" of the units that form the higher level. It is the organization that imparts the characteristics at each level, hence the name "Levels of Organization".

For the study of ecology the levels of organization that are dealt with are populations, communities, ecosystems, and, to a lesser degree, biomes, biogeographical regions, and the biosphere.

## The Ecosystem

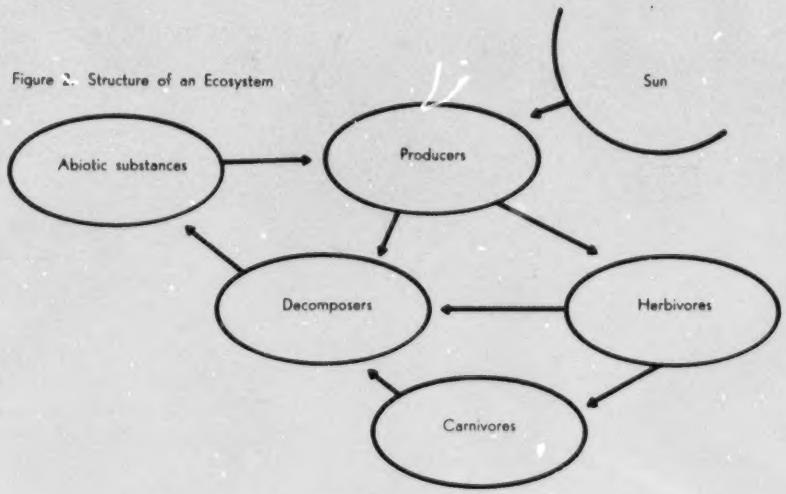
The best unit for studying the environment is the ecosystem. It is the first level of organization where the living and nonliving parts of the environment interact in the recycling of nutrients. In this way ecosystems are self-sustaining. Familiar ecosystems include a pond, and old field, a salt marsh, a forest, a river, and a coral reef just to name a few.

Two characteristics of an ecosystem are that it has both *structure* and *function*. The structure consists of the biotic and abiotic parts of the environment, and the function is to recycle nutrients by means of the action of the organisms that make up the structure.

The recycling of nutrients involves the constant process of building up and tearing down. These processes occur at all the levels of organization from molecules to ecosystems. But these processes do not happen automatically; energy is needed. The initial energy is supplied by the sun and this energy is transformed and reused as it moves through the structure of the ecosystem. (See figure 2.)

The sun's energy is converted and stored by green plants. By means of sunlight and the pigment chlorophyll, water and carbon dioxide are built up into complex food molecules in the process called photosynthesis. Plants use some of this food for their own growth and store the rest. Green plants are *producers;* this is their position or "role" in the structure of the ecosystem. They are also called "autotrophs" because they can manufacture their own food from nonliving materials.

Figure 2. Structure of an Ecosystem



The energy stored in plant bodies is passed on to animals when they feed on the green plants. Animals use the energy obtained from plants for growth and maintenance. Animals are *consumers* in the structure of the ecosystem. They are called "heterotrophs" because they cannot make their own food and obtain it by feeding on other organisms. Animals that eat only plants are herbivores; meat eaters are carnivores and those that eat both are omnivores.

When plants and animals die, their bodies are broken down and used as food by bacteria and fungae. These non-green plants absorb some of the compounds for their own use and release simpler compounds back into the soil and air. These organisms are *decomposers* in the structure of the ecosystem. They are also heterotrophs because they cannot make their own food. The compounds they release back into the soil along with the minerals found there are the *abiotic substances* used again by green plants to produce food.

Producers, consumers, decomposers and abiotic substances make up the four basic components that are the structure of an ecosystem.



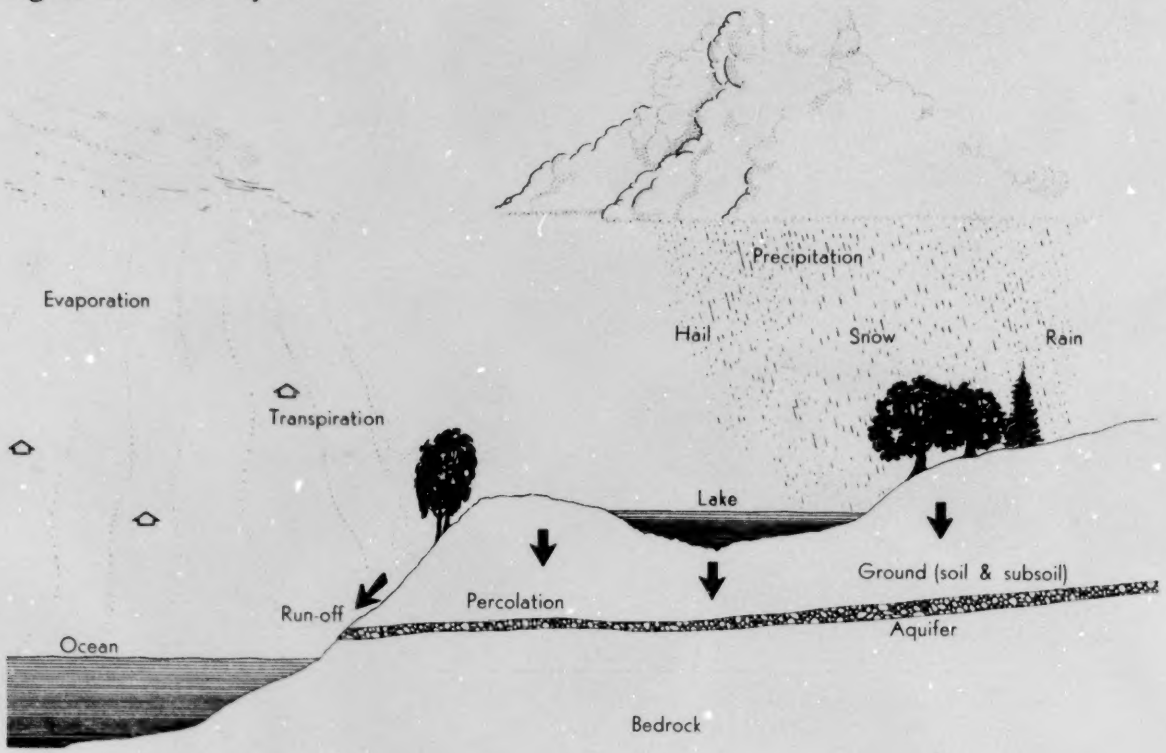
## Biogeochemical Cycles

All of the chemical elements, especially those necessary for life, tend to circulate through the structure of the ecosystem. We call these circular paths of the elements *biogeochemical cycles*, and as we study them you will see that the name is self-explanatory. The three cycles we will study are water, carbon, and nitrogen. There are many more, but these three are not only important to life but also serve to illustrate how mankind is disrupting these cycles.

**Water cycle —**

Our main source of water is the oceans. Evaporation by the sun and transpiration from plants draws water up into the atmosphere. Here it condenses into clouds and is distributed around the earth by winds. The water in the clouds precipitates back to earth in the form of rain, hail, or snow. Some of this water is used by plants and animals, some runs into rivers and lakes and eventually returns to the ocean. The remaining water in the soil moves slowly downward, or percolates, until it reaches bedrock

**Figure 3. Water cycle**



forming an aquifer. This ground water is purified as it travels through the soil. As the number of wells tapping this ground water increases, the level of water in the aquifer drops because the time required for water to percolate cannot keep up with the current demands for its use. If this trend continues we will have to find new ways of treating and reusing our water.

**Carbon cycle—**

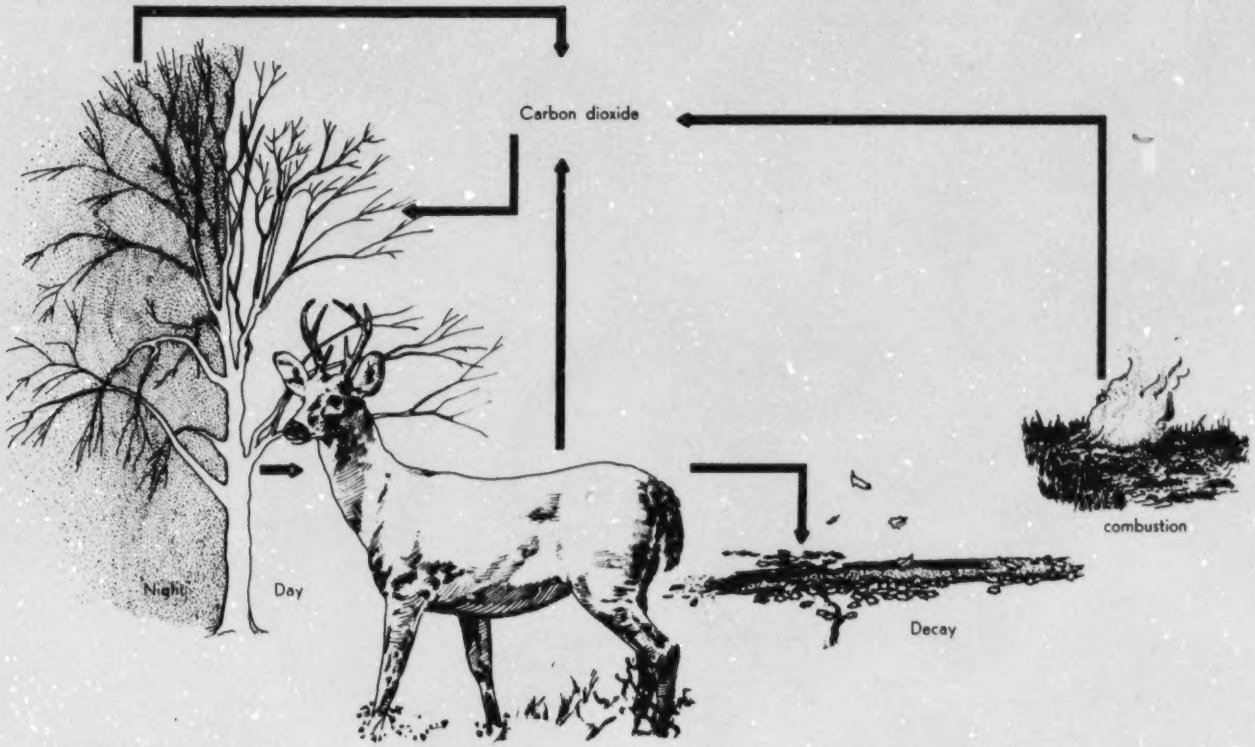
Carbon is the basic element upon which all life is built. The main source of carbon is carbon dioxide in the atmosphere. Plants use $CO_2$ to make carbohydrates, fats, and proteins. These foods are eaten by animals and the carbon is incorporated into their bodies. It is released again as $CO_2$ to the air when they breathe or when dead animals and plants decay. Plants also release $CO_2$ into the air at night when they respire. Plant and animal remains that have become buried in large geologic deposits become oil, natural gas, or coal. The burning of these fossil fuels also releases $CO_2$ back into the atmosphere.

Atmospheric carbon dioxide allows high energy solar radiation to enter our atmosphere but does not allow weaker heat waves to leave it. This is called the "greenhouse effect" because the atmosphere acts much like the glass on a greenhouse, holding heat inside. Thus the temperature of the earth's surface is raised when more $CO_2$ is present. Counteracting this effect is the fact that particulate matter from burning fuels scatters the sun's rays so that less energy reaches the ground, resulting in cooler temperatures. Scientists have not yet decided which of these effects will eventually win out, and the problem of whether the burning of so much fossil fuel will eventually cause the earth to become progressively warmer or cooler is still "up in the air".

**Nitrogen cycle —**

Since nitrogen is the element that is necessary for the formation of proteins, it is essential to life. The nitrogen cycle is somewhat more complicated because plants cannot use atmospheric nitrogen and it first must

**Figure 4. Carbon cycle**



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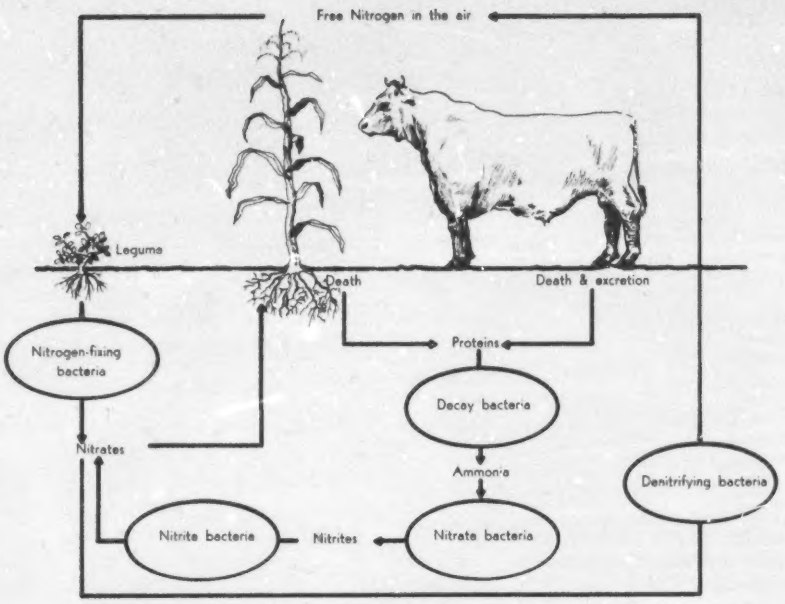



**Figure 5. Nitrogen cycle**

be converted into nitrates and nitrites before they can use it to make protein. Bacteria play an important part here because they bring about the conversions that are necessary for the recycling of these necessary nutrients. The bacteria are found in the soil (unless the ecosystem is an aquatic one) and in nodules on the roots of certain legumes such as beans and clover. The nitrogen cycle is really a cycle within a cycle. One occurs in the soil. Plants and animals die and their protein is converted back into nitrates which are taken up by living plants which are eaten by animals. The other occurs in the soil and the atmosphere. Nitrogen is removed from the air and converted to nitrates in the soil by *nitrogen fixing* bacteria. It may then be taken up and used by plants or be converted back to nitrogen again by *denitrifying* bacteria and released to the air.

Nitrates are important to plant growth, and farmers use them heavily to get good yields. But the nitrates that wash from farms into rivers and lakes are also good for the growth of aquatic plants. Rapid growth of algae, called a "bloom", occurs. Recall that plants respire at night, using up oxygen in the water and releasing $CO_2$. If they use up too much oxygen it could result in a fish kill. Algal blooms also choke waterways, give off unpleasant odors, and when they die the bacteria in the water become so numerous that they too use up the oxygen with the same result to the fish.



Nitrates also bring about a condition in lakes and rivers called *eutrophication*. This is a natural aging process that occurs over thousands of years, but when it is speeded up the results are usually harmful to the lake or river and to the organisms that live there.

In many cases man consumes materials so fast that the cycles tend to become acyclic with shortages occurring. The aim of conservation is to avoid these shortages by not putting a strain on the system.

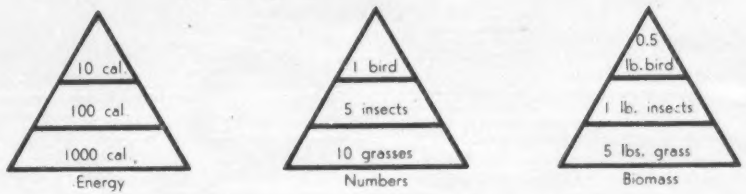
## Food Chains

We have said that the function of the ecosystem, the transfer of energy and nutrients, occurs from one organism to another within the structure. The sequence of organisms through which this energy moves is a *food chain*. In nature, food chains are complex and intertwined to form a community *food web*. All food chains or webs have certain features in common: 1. They begin with green plants in almost all cases. 2. They end with decomposers. The sequence between the producers and decomposers can vary greatly in length and complexity.

Each level in a food chain is spoken of as a *trophic* level. Producers are first trophic level, the herbivores are the second trophic level, and so on. Some energy is lost from the system as it moves through each trophic level because of the Second Law of Thermodynamics. This law states that every energy transformation involves loss of some *usable* energy. This is not hard to understand if we look at it this way. The energy a rabbit obtains from grass goes into maintaining the rabbit's body. A fox eating that rabbit doesn't get 100 per cent of the energy contained in the grass because the rabbit used some of it up in living. The total energy passed on to a higher level is usually only about 10 per cent.

The distribution of energy within a community can be represented graphically by a pyramid, where the producers are the base and the last consumer is the apex. Other features of an ecosystem can be represented by such a pyramid. For example the number of organisms in each trophic level, or the weight or biomass of organisms in each trophic level. There are exceptions to these two examples. If one bush is eaten by 20 insects the numbers pyramid would be inverted. However, the pyramid of energy is *never* inverted and is characteric of *all* ecosystems since it is determined by a physical law.

**Figure 6. Pyramids of energy, numbers and biomass**



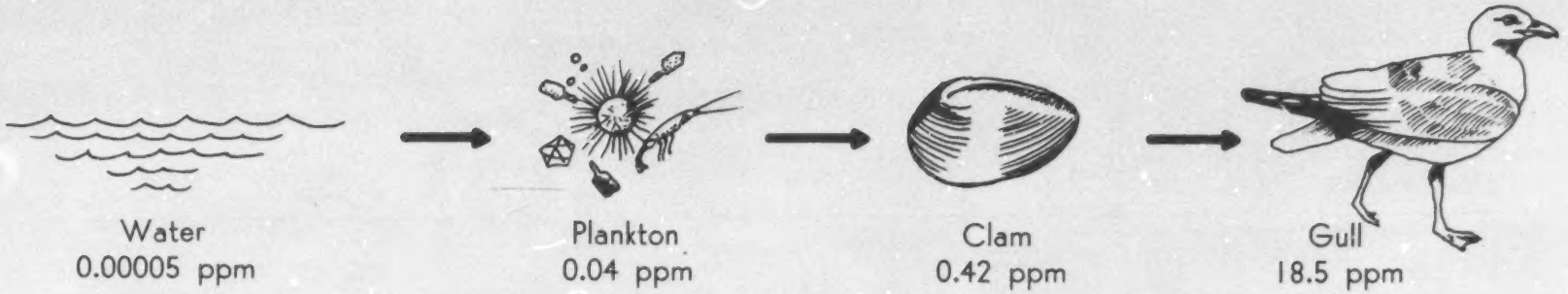



**Figure 7. Biological Magnification**

Sometimes substances other than those needed for nutrition are transfered upward in the food chain. Certain harmful substances, such as DDT, become concentrated in the bodies of the higher carnivores as they feed on the lower carnivores and herbivores whose bodies contain these substances. This increase in the concentration of residues as they move up through the trophic structure is termed *biological magnification*. When present in large amounts, they may be fatal or interfere with the animal's reproduction.

In discussing the structure and function of an ecosystem, we must keep in mind that what we are really discussing are living organisms, organisms that must adapt to a changing environment and at the same time provide themselves with the essentials of life. The three essential requirements of all organisms as individuals are: nutrition (food and water), the elimination of bodily waste, and an environment that will neutralize or carry away these wastes. In an undisturbed ecosystem these needs will be satisfied because each species in some way performs a function that directly or indirectly benefits all other species there. This role that each organism plays is termed its *niche*. The niche of phytoplankton is as a primary producer. The extent to which phytoplankton is able to perform this role is dependent on sunlight, water temperature, dissolved nutrients, crowding by other plants, grazing by herbivorous animals, disease, etc. Any variable in the life of a species that limits or governs its capacity to function determines the hypothetical "boundaries" of its niche. One of the most difficult problems in ecology is the determination of these variables and how they effect the organism and thereby the ecosystem.

Many ecological disasters have occurred because not enough was known about the niche of an organism. A good example of this happened in Boreno. The World Health Organization sprayed DDT in the villages to kill the mosquitoes. A few weeks later the roofs of the huts began to cave in. They were being eaten by caterpillars that had escaped the DDT, but the predator wasps that usually fed on the caterpillars had been killed by the DDT. So WHO personnel sprayed in the huts for the caterpillars and at the same time killed the house flies that were there. Lizards that usually stayed on the walls and ceilings of the huts ate the flies, died, and fell to the floors. Cats ate them and also died. The rat population then increased so rapidly that there was much destruction of food and a threat of plague. Finally cats had to be parachuted into the villages to restore the natural balance.

This story points up the fact that everything in nature is interrelated and that tampering with one part disrupts the entire system.

## Succession

It is a natural fact of life that nothing remains the same. We have only to revisit a place where we may have camped or hiked years before to find that open fields have become covered in shrubs or even small trees.

This process of change occurring with time in an ecosystem is called *succession*. Although the species may differ from one part of the country to the next, the patterns of change are similar. Whether it is a river, a lake, a forest, a beach, or even bare rock, it will change.

The change is brought about by the very action of the organisms in the community. When organisms occupy an area, their presence changes that area. Eventually these alterations will make this area less favorable to the first species and more favorable to other species.

Succession in an old field ecosystem is common along any country road. The *pioneer* plants are those that are able to live in open, barren soil. As these plants drop leaves or die each winter, a layer of litter builds up on the soil. As it decays the soil becomes richer and is able to hold more water. Seeds from other plants, better suited to this soil type, will now germinate and grow. As they grow they will compete and crowd

out the pioneer plants that are not as well suited to that area any more. This will continue to happen, each community type replacing another, until a stage is finally reached that is stable. This is called the *climax* community. This is not to say that this community is static, but the changes are slight and it is to a great degree self-perpetuating, even for centuries.

Several generalizations can be made about the succession of ecosystems.

1. The changes in species are usually faster in the early stages than in the later ones.
2. The total number of species (diversity) increases as the ecosystem matures.
3. The total amount of living material (biomass) and nonliving organic material increases during succession.
4. The food chains become longer and the food webs more complex.
5. Because of the greater variety in relationships, there is higher efficiency in transferring energy and less energy is lost from the system.

Most stages of succession are characterised by dominant plants in the area. Animals follow the plants and we can also determine the stage of succession by looking for certain *index* animals. These animals will only be found when a certain stage of succession is reached. For example, snails are found in a climax forest but not in the pioneer stage of an old field.

The three factors that affect plants and therefore influence successional trends are: climatic, edaphic, and biotic. *Climatic* are those factors such as temperature, rainfall, wind, and sunlight. *Edaphic* factors pertain to the soil and its properties such as pH, water holding capacity, and mineral content. *Biotic* factors are those we have already dealt with to some extent. These are the interactions between plants and animals. Succession will proceed only as fast and as far as these three factors will allow.

## Conclusion

Through the process of evolution, plants and animals have acquired the physiological adaptations to survive in a given habitat. Some organisms have very narrow ranges of tolerances while others are very hardy. Either type, however, will find it hard to adjust to sudden and drastic changes in their environment. Changes and fluctuations in the environment represent selective pressures upon a population to which it must adjust. Those which cannot adjust, disappear. And as we have learned, their disappearance affects those of us that remain.

The main point here is that the "real" structure and function of an ecosystem is a property that will probably remain unknown. But conservationists and ecologists must work together to learn as much as is possible about the environment so that man will not disrupt the natural system beyond its own capacity to recover.

# Wildlife Management

In past years wildlife management has been thought to be synonomous with game management. But today many people are interested in watching, hearing, seeing, and otherwise enjoying wildlife without hunting. It should be said that hunters have been responsible for almost all of the work and much of the money which resulted in stopping the decline of many game animals. Populations of game animals can have the annual surplus harvested with no real harm. In fact, failure to do so may prove to be detrimental in some cases. To mention the non-harvest values is not to condemn hunting, but to say rather that wildlife can be managed for other purposes. In this section we will study the principles of population ecology and how they are used in game management and how this management also helps other non-game species.

"Game management is the art of making land produce sustained annual crops of wild game for recreational use." Aldo Leopold wrote those words in 1932. This can be thought of as the birth of the science of game management. Several years later, R. H. Giles, Jr. expanded this definition by saying, "wildlife management is the science and art of changing the characteristics and interactions of habitats, wild animal populations, and men in order to achieve specific human goals by means of the wildlife resource."

Wildlife is a product of the land, and the kinds and numbers of wildlife produced usually are a result of the uses of the land. When much of the land was used for agriculture early in this century, rabbits, quail, and other farm game species were plentiful. In the past few decades much of the farm land in South Carolina has been turned into forest for the paper and lumber industry. There followed a natural change in the composition of the wildlife species to those that dwell in forest.

The job of the wildlife biologist is to try to identify the factors limiting the abundance of wild game. By controlling these factors, more wildlife can be produced for recreational use.

In the early days of game management practices there were four means of providing adequate game: control of hunting, control of predators, providing of refuges to insure breeding stock, and the artificial replenishment of game to restock uninhabited or "overshot" ranges.

## Control of Hunting

Uncontrolled hunting in the last century was probably a contributing factor to the extinction of the passenger pigeon, the heath hen, the great auk, Labrador duck, and the Eastern elk. Others such as the cougar and the timber wolf are close to extinction, although loss of habitat accounts for most of the endangered species. If they are given protection from indiscriminate slaughter, many species can recover; others because of their particular breeding habits or loss of habitat cannot recover. *Legal* hunting for sport has not caused a single species to be added to the list of rare and endangered species.

For some wildlife, the removal of surplus individuals is a beneficial part of management. Many kinds of wild game, rabbits for example, respond to an increased fall hunting harvest through greater breeding success and survival of the young. In these instances the population is said to have a high "turnover" rate. However, hunting may exterminate any game whose range has been restricted to small areas. For example, migratory waterfowl prefer habitats now in limited supply and where hunting is often concentrated. Limitation of hunting is important to assure survival of a breeding stock of these species. It is also needed in areas where new

animals have just been transplanted. On the other hand, man is the only natural predator for deer now that the other ones such as wolves and cougars are gone. Without hunting, deer would cause substantial crop damage in some areas of our state.

## Control of Predators

Control of predators was widely practiced in colonial times in the eastern states and, until fairly recent times, in western livestock country. Many states had bounties on wolves, mountain lions, bobcats, and foxes. Now these are considered a waste of funds, and many predators are protected because they are endangered species. Predatory birds have been reduced through the use of pesticides because these chlorinated hydrocarbons interfere with the reproductive systems of the birds.

There is the case of a private game club that specialized in quail. The manager of this club ordered hunters and employees to shoot any hawk on sight because the hawks were predators on the quail. One season there were no quail, so the manager called on the state game biologist for advice. When the biologist got the to the club and looked around, the first question he asked was, "Where are your hawks?" The manager, of course, said they had all been shot to protect the quail. Then the game biologist explained that the hawks may take a few quail, but they also prey on many rats and skunks which eat quail eggs. Needless to say, the manager of that club is now the biggest hawk protector in the state. We learned long ago that you don't benefit a species by destroying another species.

## Refuges

Refuges have proved to be valuable only for certain species. Refuges for migratory waterfowl are an important means of assuring a breeding stock because waterfowl hunting may take two-fifths of the fall flight because the birds are concentrated in given areas. Although primarily established for migratory waterfowl, many refuges now are used also to enhance and protect endangered wildlife. Refuges have also been used as an immediate protection for transplanted native big game. However when harvest is too limited the animals may become overpopulated and seriously damage the range.

## Artificial Stocking

Artificial stocking of birds and animals reared on game farms has been a costly and generally inefficient method of providing hunting. These are called "put and take" areas. There is generally no sport to shooting domesticated birds, and if too much time elapses between when they are released and when they are hunted, many will have already died because they are not suited to compete in a wild environment.

Artificial stocking of birds and mammals in ranges already occupied by the same species is also limited in success because of the principal called "carrying capacity". Carrying capacity is the number of individuals that the habitat can support. This not only refers to food and water, but also to escape cover, nesting cover, loafing areas, brood and feeding areas. Wild game animals normally produce more than ample young to fill all the available home range. Any farm-reared animals released into the occupied range are usually the first to be lost when the carrying capacity is exceeded. Even increased knowledge of management techniques cannot get around the long-established principle that wild animals cannot be "stock-piled" in excess of the carrying capacity of their environment.

Here is an illustration of how environmental factors, including hunting, affect the population of a deer herd and how game biologists use this information. Suppose there is a certain area which will support a population of 100 white-tailed deer. The number 100 is the carrying capacity of the environment. First it is important to know how many of these deer are female and of these, how many are of reproductive age. This will determine the number of fawns born in the spring. Also affecting reproduction will be the general health of these deer. If 75 fawns are born, the population of the herd will rise to 175. This number is too high for the habitat to support. Now suppose during the summer 10 of the older animals die of accidents or are preyed upon and 10 of the new crop of fawns are the victims of predators. With a total mortality of 20, this now brings the herd size to 155 at the beginning of fall and winter. This is still too many for the available habitat. Two things can happen at this point: 1. The size of the herd can continue to expand next year until the deer have browsed the habitat beyond recovery and spread disease and parasites in a too dense herd that is now also undernourished. During harsh months a massive die-off will occur that will bring the population of the herd way down to just 10 or 20 animals; or 2. hunters can be allowed to go into the area in the fall and harvest the excess animals, keeping the herd at the proper level, preventing habitat destruction and the massive die-off.

It is the job of the game biologist to know what this allowable harvest should be, based on data he has compiled from previous years. He can then suggest the length of the deer season, the possibilities of doe-days and set the bag limit.

## Habitat Improvement

The only real way to have more wildlife is to have habitat improvement. In this way the carrying capacity of the environment can be raised to a higher level. Habitat improvement means supplying those conditions needed by a species to reproduce and survive. These conditions have already been mentioned (food, water, cover, etc.). This may mean creating clearings in a forest area or planting browse food in the clearings made by powerline rights-of-way.

As important as the kind and amount of food is the positioning, configuration, and size of the planted areas. This element of habitat is called "interspersion." Many wildlife species require more than one type of habitat. The bob white quail do best in a transition habitat of fallow fields, woodland, brushland, and cultivated land. There will generally be more different kinds of animals in the zone between two habitats than in either of the two habitats. This is called the "edge effect." It is these edges that are most used for feeding, loafing, resting, calling, and nesting. The more the different habitats are interspersed, the more edges there will be.

Only recently wildlife ecologists have begun to understand that the management of wildlife is really the management of people. The numbers

of hunters and their traditions, and the demand for non-hunting use have brought problems the game manager must deal with.

Each habitat is constantly being modified by natural processes and by economic and social forces that together make up America's culture and growth. But wild game is a product of the land and will change as the land does, and no public opinion, demand, or politics will prevent its changing with the ecology of the land.

## Fresh Water Ecosystems

After mastering the concepts in the first section, we are now ready to discuss some specific kinds of ecosystems. Since three fourths of the world is water, these habitats are of primary importance. The study of fresh water systems is called *limnology* and the study of marine systems is called *oceanography*. We will deal first with the fresh water habitats and how they affect fisheries management programs.

Limnology is the study of fresh or inland waters. Some inland waters have odd compositions of chemicals, so this study includes the geology, chemistry, physics, and biology of these waters. From our knowledge of the water cycle, we know that the waters of inland lakes and rivers come from precipitation (rain, snow, sleet), but this precipitation is not evenly distributed over the earth. At the equator rainfall is seasonal, and as one moves toward the temperate zones, it is more evenly distributed over the year. South Carolina averages 50-52 inches per year, but Caesar's Head has the highest rainfall in the state with over 90 inches per year.

On large continents warm moist air over the ocean is carried by winds to the land. As this air rises it cools, and the rain precipitates on the ocean side of the mountains. The interior of the continent is usually hotter and drier.

The basic sources of most inland waters are run-off and ground water. In this part of the country ground water seeps down to bedrock and becomes concentrated in a gravel layer that lies below the hard clay and limestone layers of the surface. This gravel and water layer is the *aquifer* that flows slowly downhill. It moves so slowly that this water may be 100 years old before it reaches the artesian systems of our coastal plain.

### Lakes

Closed basins, or lakes, are formed in several different ways. The largest lakes in the world are formed by faults which are large cracks in the earth's surface caused by movements in the crust. Smaller lakes, often called crater lakes, may be formed by *volcanic* activity. Sometimes the molten lava contains large bubbles that solidify; when the top of the bubble erodes away, a basin is formed which can fill with water to make a lake. Lakes are also formed by *glacial* activity. Glaciers move southward because of ice being added at the northern extremes. As they move they bulldoze the ground with a rounded blade. This causes a mound of dirt to be pushed up on either side and in front of the advancing glacier. These mounds of dirt are called lateral and terminal *moraines* respectively. When the glacier melts and recedes, it leaves these piles of dirt behind. If a moraine is left across a valley and dams it up, a lake is formed. Lateral moraines may form lakes by damming up streams that flow into the main river bed dug out by the glacier. If the main valley is dug out by the glacier but the side stream is not dammed, it may result in a waterfall. Sometimes the glacier may cross an old lake bed. As it digs it deeper, the glacier may change the shape of the lake and also the course of the river that drains it. This is what happened to the Great Lakes. They used to drain into the Gulf of Mexico instead of the Gulf of St. Lawrence.

Most of the bodies of water in South Carolina are man-made. The larger lakes were constructed to generate electricity; the smaller ones were made by developers and private landowners for boating, swimming, and fishing. Most of these man-made lakes and ponds are fed by surface run-off and lose water into the ground. Carolina bays are a unique type of basin and for a more detailed discussion read the article, "A Carolina Bay Is Saved" in volume 19, number V, of the 1972 *South Carolina Wildlife Magazine*.

### Stratification in Lakes

In the temperate regions of the world, lakes and ponds undergo a yearly cycle of stratification and mixing. To understand how these events occur, we must first review some of the properties of water. Water is 750 times denser than air. This affects organisms by giving them buoyancy, but protoplasm is a little heavier than water so organisms must still find ways to keep from sinking.

The density of water varies with temperature. As the temperature of water *decreases*, the density *increases*. This factor is not only important to the organisms that live in the water, it is also what determines the stratification (the separation of the water into distinct layers) of lakes and ponds. This increase in density occurs until the temperature of 4°C is reached. At temperatures below this the water molecules tend to arrange themselves into a crystal structure. There is a definite spacing in the crystal so that from 3°C to 0°C water becomes less dense. Therefore, water that is colder than 4°C is lighter and tends to remain on the surface.

During the winter in temperate zones lakes are frozen for the most part. (See Figure 8.) Spring winds, plus the sinking of less dense water as the ice melts, bring about a complete mixing of the waters of a lake. This is the "spring turnover." As summer progresses, the surface waters are warmed, become lighter, and stay on top. The layer of warm surface water and the colder bottom water do not mix. Between them is a thin layer called the *thermocline* where the temperature changes rapidly. Once these layers are established, they are cut off from each other and the lake is in what is called "summer stagnation." As the days become cooler in the fall, the surface water loses heat and begins to mix with the lower layer. This is called "fall turnover." Once again the waters of the lake are uniformly mixed. They will remain this way until ice forms and "winter stagnation" sets in again. By this process, twice a year the nutrients that have sunk and become trapped in the lower depths are again brought to the surface and mixed to be utilized by the plants and animals.

As we have seen, temperature affects density. Now we should consider the other properties of water and how they affect the organisms that live there. Temperature also affects the amount of dissolved gases contained in water. The higher the temperature, the less oxygen and carbon dioxide the

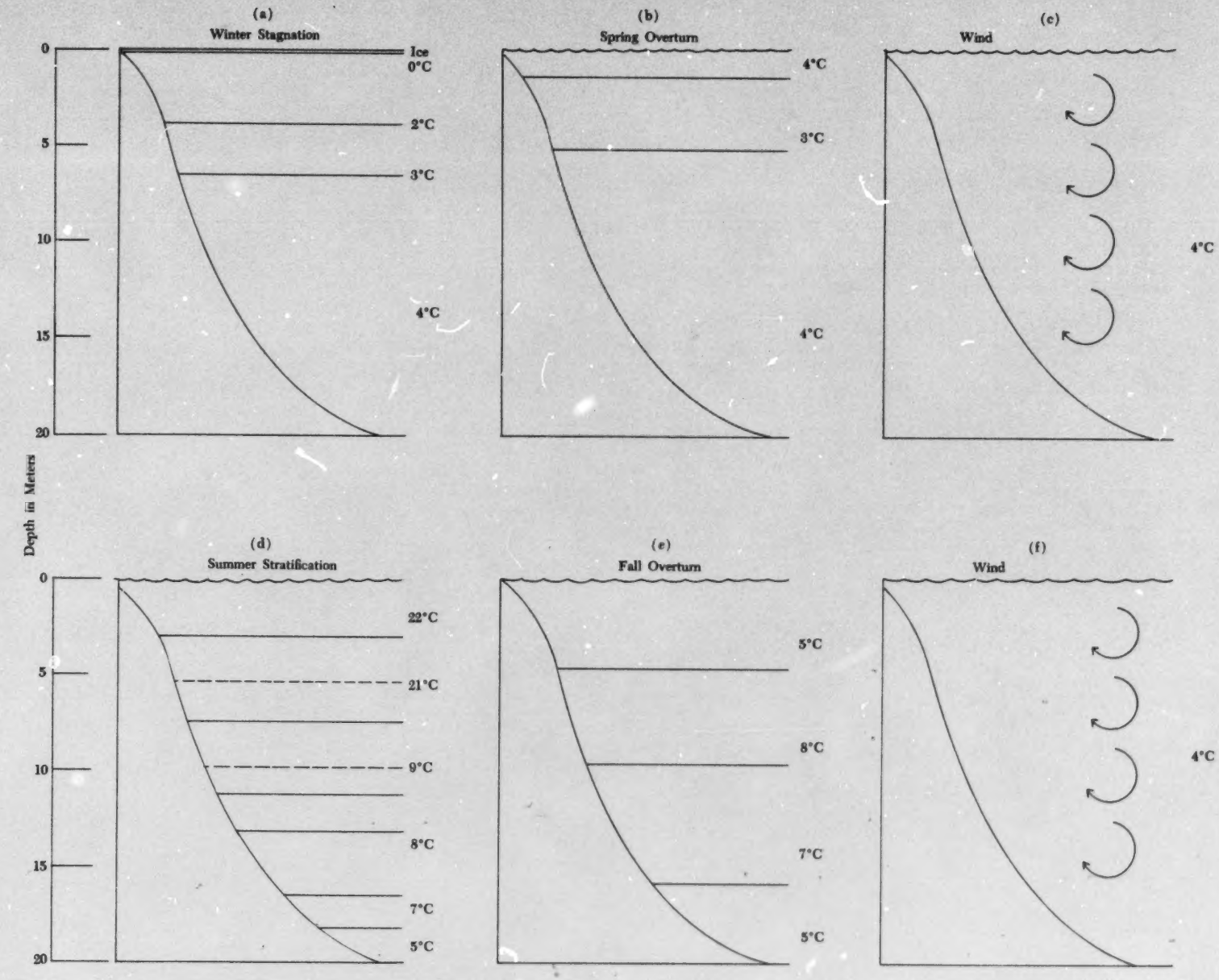



Figure 8. Stratification in Lakes



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water will hold. As a lake becomes stratified as to temperature, it also becomes stratified as to dissolved gases. Dissolved gases are more abundant in deep water, except for oxygen. Carbon dioxide comes from the metabolism of the bottom organisms. At spring circulation, oxygen is homogeneous throughout the water. With the onset of stratification, the oxygen distribution changes as the water layers become cut off from one another. In the upper layers, where the plants produce it, oxygen content is still high, but in the lower water, below the penetration of light, the oxygen is used up by the bottom organisms and is not replaced.

Light is an important factor to aquatic plants, of course. As light penetrates water, certain wavelengths are absorbed selectively. In the first three feet, almost one-half of the infra-red light is absorbed. Infra-red is relatively weak and these wavelengths cannot penetrate to any great depth. The blue and ultraviolet wavelengths penetrate deeper because they are stronger. Objects that are red at the surface appear grey or black in deeper water. The wavelengths that are used most by plants to manufacture food are the red and blue ones; therefore, green plants must remain in the upper sunlight area to live. If they sink below this level, they die and are lost to the bottom. Later we will discuss how plants solve this problem.

## Succession in Lakes

All lake basins have a tendency to fill in. (See Figure 9.) The action of waves cutting against banks sends sand to the bottom, and wind-driven sand, pollen, and leaves all act to fill the lake. Once filling starts, rooted aquatic plants add more material to the bottom. As the lake becomes shallow, the plants along the shore (reeds and sedges) advance. As more and more filling takes place, land plants take root and the lake soon becomes a bog and eventually a land area.

Figure 9. Succession in Lakes

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## Formation of Rivers

Most streams form from what is initially a flat surface. As it rains, small streams cut into the land, and erosion eventually causes these smaller streams to become larger and more permanent. As years go by and the river bed is cut deeper and deeper, erosion will also round off the valley sides and top until, finally, a wide valley is formed with a stream in the center surrounded by rolling hills.

A part of the aging process of a stream is its *meandering*. This might be caused by boulders or trees falling into the stream. Sand and silt settle around these obstacles, and the current shifts to the other bank. Finally the current cuts through to form an island. The main current is then straight with slow, backward currents, called *eddy currents*, on either side of the island. These eddy currents deposit silt and plug up the curves to form an "ox bow" lake. These lakes are usually found in old river systems and tend to widen the valley (See figure 10). Ox bows usually fill in with vegetation and become *flood plains*. Flood plains are important in the conservation of plant and animal species, for flood control, and for natural beauty. When channels are "controlled" and straightened, the velocity of the water is high, and during flood conditions the natural tendency of a river to cut a new channel *cannot* be prevented, and the river will again meander. Channelization is costly, unsightly, detrimental to wildlife and futile.

The velocity of a river depends on its depth and width. In turn the velocity determines how much silt the river can carry. With a slower velocity the amount and size of the material carried is decreased, so when a river floods its banks, the spreading out of the water slows the current, causing silt to settle out along the river bank as a *levee*. Levees are found only in old, well established river systems. Natural levees are also found along the creeks of salt marshes.

The velocity in a river is unequal and varies in all parts of the stream. It is faster in the middle and slower nearer the bank. This is an important consideration for the inhabitants of the stream. Many species of organisms have different requirements, water velocity being just one. A natural stream with many curves and velocities will have more home sites for animals than one that has been straightened.

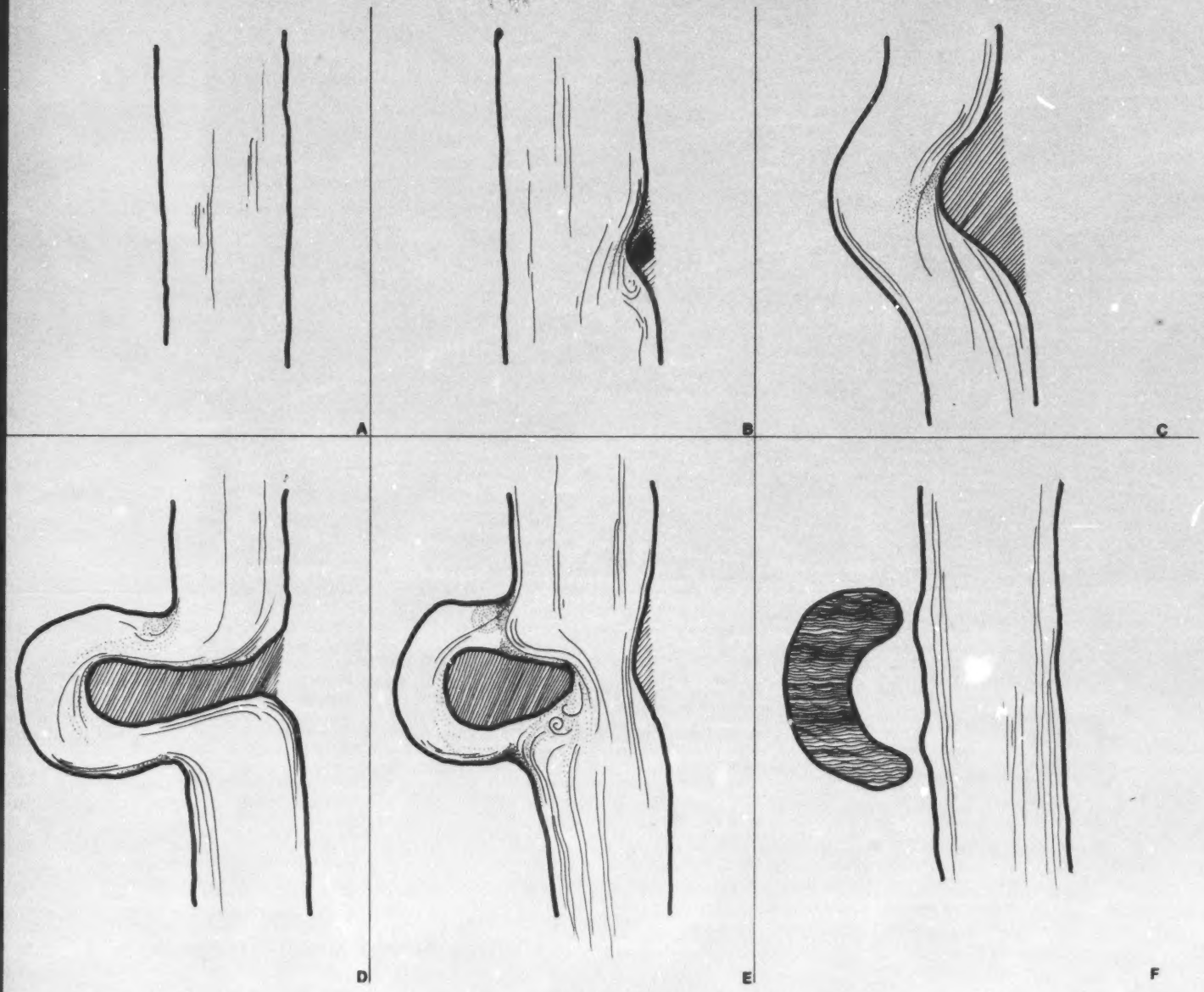


Figure 10. Formation of Ox Bow Lakes

Large river systems tend to build *deltas*, which are formed when a smaller body of water empties into a larger one resulting in reduced current speed and deposition of silt. This feature is exemplified by the Mississippi, the Nile, and our own Santee. Delta are flat land surfaces that will eventually, in a few thousand years, be uplifted by geologic forces only to be eroded again into a river valley.

## Aquatic Organisms

An interesting part of studying aquatic organisms is the adaptations they have acquired for their watery existence. Adaptation can be found in the most primative one-celled organisms to higher plants and animals.

Again sinking is one of the basic problems of aquatic organisms, especially the smaller creatures of the plankton community. They have evolved several means of overcoming this problem. One way is by increasing the surface areas of their bodies, thereby providing more friction with the water. Some algae have done this by evolving elongated projections that extend from the body at various angles (See figure 11). The water flea *Daphnia cucullata* has been observed to change the shape of its head according to the season (See figure 12). Algae also counteract sinking by storing excess food reserves, not in the form of starch as most plants do, but in the form of oil, which, as we have observed, floats on top of water.

Rooted aquatic plants that grow at the water's edge or partly submerged have also adjusted to this habitat. Their roots remain soaked all the time, and oxygen is not present in the ooze as it is in well aerated soil. To compensate for this the stems, roots, and leaves have extensive air canals to bring needed oxygen to the roots. Plants that grow in deeper water have floating leaves. These are the familiar water lilies. Here the adaptation has been the shifting of the stomata (openings in the surface of the leaf through which $CO_2$ and $O_2$ pass) from the underside of the leaf to the top surface.

The aeration system in these plants has afforded a number of animals the opportunity to live at least part of their life cycles totally beneath the water. Some insect larvae do this by boring into the air tubes of the plants with two projections on the abdomen, thereby receiving the necessary gas for respiration.

Organisms that reside in swift running streams have evolved even more specialized adaptations to their environment. Most of these adaptations are means to keep from being swept downstream. The attached algae have thin flexible bodies that sway with the current rather than being broken by it. Even their gelatinous coating that we think of as "slime" is a way to lessen the friction of the water. Animal's bodies have become flattened so that the water sweeps over them as they lie along rocks in the stream bed. Many insect larvae have hooks or powerful suction cups which enable them to cling to the substrate. It is interesting to note that animals which are smaller, or live in the cracks of rocks do not have these adaptions, even though they may be found only inches from the ones who must fight the current.

Fast moving streams that spill over rocks are well aerated and colder than slow moving streams with frequent pools that are warmed by the sun. Very different animals and plants will occur in these two areas because the ones that are accustomed to cold water with a high oxygen content cannot live in the warm water where the oxygen is lower. With a little practice one can learn to make a good guess at what the temperature and dissolved oxygen are by the type of animals found there.

## Fisheries Management

Fisheries management is the practical application of the concepts of ecology. If a person is to be successful at fisheries management he must follow what these laws dictate. The goal of most pond owners is to have plenty of big fish to catch. Many think the way to do this is simply dump a lot of bass or blue gills into the pond and let them grow up. This will not happen. As we already know, to have big fish there must be little fish also. In a balanced pond environment, there should be an abundance of plant life, small minnows, blue gills, and bass. Since this is an artificial system, it can be forced into higher production by the addition of fertilizer to get a greater abundance of algae. (This is not good for large natural systems that are uncontrolled). But there is a limit to which an artificial

**Figure 11. Adaptations in Algae**

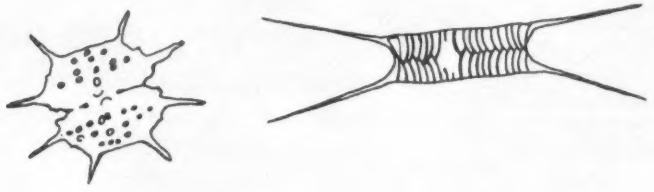

**Figure 12. Adaptations in Daphnia**

system can be pushed. There is only a certain amount of food and space available. There must not be so many blue gills that they are in competition with each other and do not get enough food for proper growth. As we have already seen, each part of nature depends on every other part, and to have large bass there must be an ample number of organisms in the lower part of the food chain. The pyramid of energy is still valid in aquatic ecosystems.

## The Estuarine Environment

The eminent marine microbiologist ZoBell uses the word "transition" to describe the estuarine environment. The term, by its dictionary definition, means: change in state, condition, or location; passage from one place or state to another. "There is no better term to embrace all of the interacting biochemical, physiochemical, geochemical and mechanical forces or processes and resultant conditions which characterize estuaries. In mod talk, this is 'where the action is.'" It is hoped that by the time you complete this section, you will come to realize the full impact of his words.

An estuary is a river mouth where tidal action brings about a mixing of salt water from the ocean and fresh water from upland streams and rivers. Inlets, bays, tidal marshes, and bodies of water behind barrier islands are all included under the heading estuarine zone. Although the salinity is intermediate between fresh water and sea water, most of the aquatic organisms that live in this zone are of marine origin, while the semi-aquatic organisms, such as some of the grasses and mammals, may come from terrestrial and fresh water origins. Estuaries have extreme biological importance in their own right and also have numerous distinct types of habitats along their borders. Because these habitats represent a transition between the aquatic and terrestrial zones, there is much interaction between them. For example, the bordering salt marshes have a high production of plant material which is exported by the tide and carried to the estuary where it is utilized by the animals there.

Because of the complex nature of climatic conditions influencing this border region of the estuaries, different habitat types have evolved in various parts of the world. Mangrove swamps dominate in the tropical regions, whereas *Spartina* marshes are the dominant vegetational type in South Carolina and in other parts of the temperate zone.

### Marsh Formation

Let us look now at how we came to have this unique coastal area. Centuries ago, before the last ice age, the coastline of South Carolina was far inland from its present location. This old coastline, known as the "fall line", is located near Columbia and runs from Richmond, Va. to Mobile, Ala. Then much of the ocean's water went into forming the sheets of glaciers in the north. Some were as much as two miles thick. This lowered the sea level, causing our coastline to extend farther to the east than at present. As the glaciers began to melt, about 15,000 years ago, the sea level began to slowly rise again, until the present-day level was reached. Most marshes are near estuaries which are the drowned lower ends of rivers caused by these rising waters. From Albemarle Sound, N. C. to the northern coast of Florida, the marshes are almost unbroken except for the large rivers.

Salt marshes are formed by the interaction of four forces: the tides, the living plants, sedimentation, and the changing level of the sea. Development of the marsh proceeds quickly once a plant takes root on a sand or mud bar. The new stems slow the tidal current so that some of the sediment load is deposited among the stems. Most of the silt is brought down by rivers such as the Santee and the Pee Dee. The plants not only trap sediment particles but they also create new debris as they die and decay. As this happens the ground level of the marsh rises and the marsh grass grows and spreads. The fine silt mixed with old roots form the marsh peat which is the base of the marsh.

If the sea level rises slightly faster than the plant growth can add to the surface of the marsh, then the surface will be flooded more frequently with sediment-laden water. The accumulation of mud on the surface will increase, keeping the marsh level on balance with the sea level. If the sea level drops, the mud will dry out, the plants will die, and flooding by rain or high tides will erode the surface to bring it down to sea level again. Thus there is an equilibrium between the land surface and the level of the sea. The changing sea level is significant only when viewed in terms of thousands of years.

### Marsh Zonation

The elevation of the land that results when sediment is trapped in the *Spartina*, along with the height of the tides, brings about successional changes and new plants invade certain areas. Different species of animals are adapted to the particular environment associated with each of these zones. Figure 13 is a diagrammatic representation of the South Carolina coast and the vegetation that is typical in each of these areas.

Starting with the open beach we will move landward to discuss each of these successional zones. The first one is composed of sand dunes with their cover of sea oats. These plants help stabilize the dunes, thereby retarding beach erosion. Depending on its size, the barrier island may be covered just with cedars and myrtles; larger ones may have matured to a climax of live oaks and magnolias. Behind the barrier island there is the expanse of the salt marsh cut by tidal creeks and then the high land. The occurrence of different plants found in the marsh is determined by the elevation of the land, the frequency of flooding, and the runoff of fresh water from the land.

On the landward side of the barrier island there is often, but not always, a grass called *Distichlis* which is only flooded on the spring, or highest high tides. It slightly resembles Bermuda grass and is the favorite egg-laying site for the salt marsh mosquito which, in fact, will lay its eggs only on this plant and only at a certain tide level.

Between the tidal creeks and the high land there is the expanse of *Spartina*. More will be said later of this amazing plant.

Beyond the *Spartina* where the soil is sandy and closer to the high land grows an often inconspicuous plant called *Salicornia*. Its common name is glasswort because its stem is made up of a series of swollen joints that break easily if the plant is handled roughly.

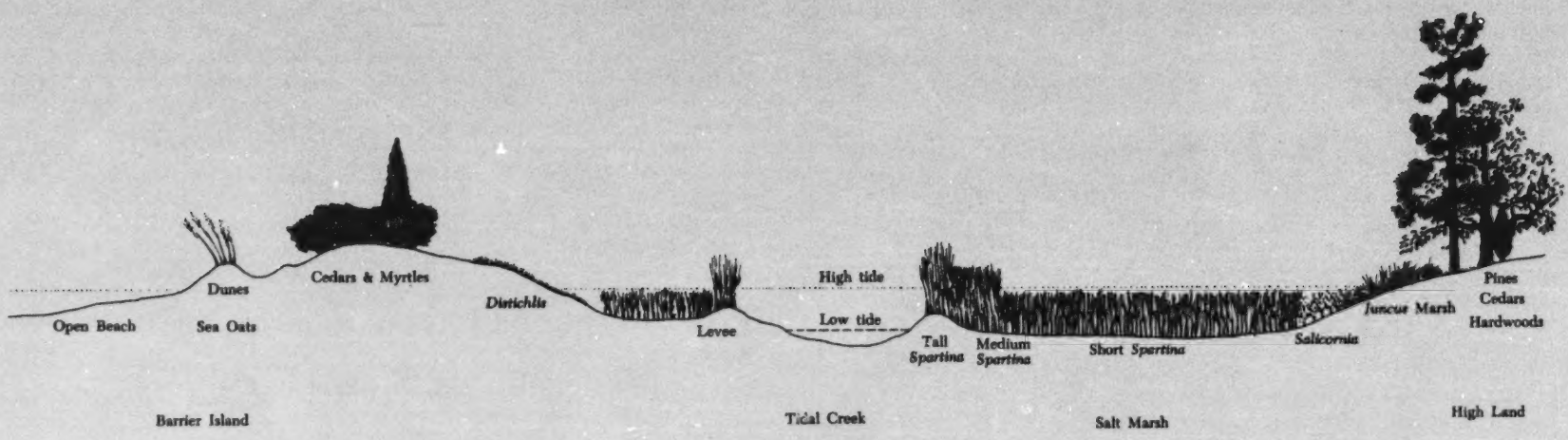


**Figure 13. Marsh Zonation**

Above the *Salicornia* is the *Juncus* marsh. This marks the zone nearest the land where tidal action is reduced. Wherever there is *Juncus*, you can be sure that the area is one with little tidal action, even if it is not always near the high land.

Each of these plants is suited to its environment because its particular requirements of salinity and tidal flooding are being met.

## Marsh Plants

A large portion of the marsh is covered by a single species of plant, *Spartina alterniflora* which exhibits three distinct forms according to the conditions where it grows. In the higher reaches of the marsh it is short; nearer the creeks it is of medium height; and at the edge of the creeks it is tall.

*Spartina* is a very special plant. It has evolved the capacity to take in salt water and convert it to fresh water by eliminating salt through its leaves Marsh grass is also very productive. By this we mean that it produces a lot of growth in a short time. Ton after ton of marsh grass is produced on each acre every year. It is twice as productive as rice and wheat fields and four times more productive than corn fields. It should be noted that this high production is reached without any imput of manpower to cultivate it and without added fertilizer.

Unlike terrestrial plants very little of the marsh grass is eaten while it is green and growing. When it dies, large mats of grass become trapped in the higher reaches of the marsh, or it may float into nearby creeks. Either way, it is broken down by bacteria and fungi into small particles. It is in this form that marsh grass is consumed by estuarine animals. One of the most conspicuous areas of the estuaries and tidal creeks is the oyster and mussel community. Since these organisms feed by filtering materials from the water, the breakdown of *Spartina* is of major importance.

There are two other types of plants that contribute to the overall production in the estuarine zone. One is the mud algae, mostly diatoms, that at times color the mud banks golden brown. Far from being barren, these are sites of intense photosynthesis. The other type, as in other aquatic environments, is phytoplankton. These microscopic algae, mostly dinoflagellates, are an important source of food for the filter-feeders. Dinoflagellates are the organisms that make up the "red tides" which occur seasonally in certain regions of the world. They excrete a powerful poison which can cause the destruction of millions of fish and can also make shellfish a potential hazard to humans.

These three production units, the marsh grass, the mud algae, and the phytoplankton, form the basis of the food chain, not only for animals of the estuarine zone, but also for many species that live in the shallow-water zone on the continental shelf and use the estuary as a nursery ground before migrating to the open sea.

## Physical Conditions

The physical conditions that the animals living in an estuarine zone must cope with are extreme. Suppose you are a snail living along the mud bar of a creek. In the summer, temperatures may reach 95°F during the day and then drop to 75°F when the tide comes in. At the same time the salinity of the tidal pools along your creek may exceed 60 ppt (parts per thousand) from evaporation during a hot day and then drop to 2 ppt if a thunderstorm occurs. When the tide returns, it's back to the normal 30 ppt again. The winter is not much better. When the bar is exposed at low tide, the air temperature may be 20°F and, when the tide comes in, the temperature of the water may be 50°F.

Some of the other conditions that may be changing at the same time could be pH, oxygen or other gasses, radiation, turbidity, turbulence of the water, and the occurrence of other organisms as potential food or enemies. In addition, these changes are occurring horizontally, vertically, daily, intertidally, and seasonally. Variability or transition is a key characteristic of this environment, and the organisms living here must be able to withstand an enormous range of environmental conditions.

In addition to all of these natural influences, the estuarine organisms have to cope with the insults that man imposes: new chemicals and pesticides, highways constructed across the marsh that stop the vital tidal flow, dredging, filling, dumping, and almost any other conceivable thing that can be done.



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## Conclusion

The primary role of the South Carolina Wildlife and Marine Resources Department in the state's estuaries is to conduct research to determine means by which the commercial shellfish and fisheries yield can be improved, to provide habitats for sport fish along our coast, and to set shrimping seasons. In addition, the research vessel *Dolphin* surveys the continental shelf, and smaller vessels conduct surveys in several of the state's rivers. Proposed development sites are studied and recommendations are made to the Coast Guard and the Corps of Engineers as to their impact on the environment.

To quote Aldo Leopold in *A Sand County Almanac*, "By and large, our present problem is one of attitudes and implements. We are remodeling the Alhambra with a steamshovel, and we are proud of our yardage. We shall hardly relinquish the shovel, which after all has many good points, but we are in need of gentler and more objective criteria for its successful use."

The delicate ecosystem of our coast cannot stand such abuse and still perform all the seen and unseen vital functions that we and all creatures require.